DOE F 1325.8
(8-89)
EFG (07-90)

United States Government | Department of Energy

Memorandum

DATE: MAR 1 1 2009

REPLY TO ATTN OF: EM-63 (Dr. James M. Shuler, 301-903-5513)

SUBJECT: Revision 2 to DOE CoC USA/9977/B(M)F-96 (DOE)

TO: Paul Mann, NA-172

Revision 2 of Certificate of Compliance USA/9977/B(M)F-96 (DOE) for the 9977 package is issued to add Isentropic Compression Experiment (ICE) apparatus as a content. The ICE apparatus consists of a stainless steel assembly containing about 8 grams of ^{239}Pu or its dose equivalent. The justification for the ICE apparatus is based on the *Application for Contents Amendment for Shipping Isentropic Compression Experiment (ICE) Apparatus in 9977 Packaging*, Revision 2, which was submitted under signature on February 20, 2009. The ICE apparatus is approved as a content for Revision 2 of Certificate of Compliance USA/9977/B(M)F-96 (DOE). The expiration date of Revision 2 is October 31, 2012.

If you have any questions, please call Dr. James M. Shuler at (301) 903-5513.

Sincerely,

Dae Y. Chung
Headquarters Certifying Official
Deputy Assistant Secretary
Office of Safety Management and Operations
Office of Environmental Management

Attachment

cc w/att.:
James Shuler, EM-63
Stephen O'Connor, EM-63
Steven Bellamy, WSRC

Department of Energy
Washington, DC 20585

PACKAGE CERTIFICATION APPROVAL RECORD
Certificate of Compliance USA/9977/B(M)F-96 (DOE), Revision 2
9977

Docket 09-05-9977

Revision 2 of Certificate of Compliance USA/9977/B(M)F-96 (DOE) for the 9977 package is issued to add to add Isentropic Compression Experiment (ICE) apparatus as a content. The ICE apparatus consists of a stainless steel assembly containing about 8 grams of ^{239}Pu or its dose equivalent. The ICE apparatus is considered to be bounded by Addendum Content Envelopes AC.3 and AC.4, plutonium/uranium metals with differing ^{240}Pu limits for the Model 9977 Package SARP. The justification for the ICE apparatus is based on the *Application for Contents Amendment for Shipping Isentropic Compression Experiment (ICE) Apparatus in 9977 Packaging*, National Nuclear Security Agency Memorandum from Paul T. Mann, Facility Operations Division, NA-172.1, to James M. Shuler, Office of Packaging and Transportation Safety, EM-63, Revision 2, February 20, 2009. The ICE apparatus is approved as a content for Revision 2 of Certificate of Compliance USA/9977/B(M)F-96 (DOE). The expiration date of Revision 2 is October 31, 2012.

This certificate constitutes authority for the Department of Energy to use the 9977 for shipment of the authorized contents under 49 CFR 173.7(d).

Dae Y. Chung
Headquarters Certifying Official
Deputy Assistant Secretary
Safety Management and Operations
Office of Environmental Management

Date: 3/11/09

DOE F 5822.1
(5-85)
(Formerly EV-618)

U S DEPARTMENT OF ENERGY
CERTIFICATE OF COMPLIANCE
For Radioactive Materials Packages

OMB Approval
No. 1910-2000

1a. Certificate Number	1b. Revision No	1c. Package Identification No.	1d. Page No.	1e. Total No. Pages
9977	2	USA/9977/B(M)F-96 (DOE)	1	17

2. PREAMBLE

2a. This certificate is issued under the authority of 49CFR Part 173.7(d)

2b. The packaging and contents described in Item 5 below meet the safety standards set forth in subpart E, "Package Approval Standards" and subpart F, "Package and Special Form Tests" Title 10, Code of Federal Regulations, Part 71.

2c. This certificate does not relieve the consignor from compliance with any requirement of the regulations of the U.S. Department of Transportation or other applicable regulatory agencies, including the government of any country through or into which the package will be transported.

3. This certificate is issued on the basis of a safety analysis report of the package design or application —

(1) Prepared by (*Name and Address*):	(2) Title and identification of report or application:	(3) Date:
U.S. Department of Energy Savannah River Operations Office P.O. Box A Aiken, South Carolina 29808	Safety Analysis Report for Packaging Model 9977 B(M)F-96 S-SARP-G-00001, Revision 2, August 2007; as supplemented [See 5.(e)]	August 2007

4. CONDITIONS
This certificate is conditional upon fulfilling of the applicable Operational and Quality Assurance requirements of 49CFR parts 100 – 199 and 10CFR Part 71, and the conditions specified in Item 5 below.

5. Description of Packaging and Authorized Contents, Model Number, Transport Index, other Conditions, and References:

(a) Packaging

(1) Model Number: 9977

(2) Description:

The 9977 is designed to ship radioactive contents in assemblies of Radioisotope Thermoelectric Generators (RTGs), 3013 Containers, Engineered Containers or arrangements of nested food-pack cans. The components of the package include the drum, insulation, Containment Vessel (CV), Load Distribution Fixtures (LDFs), and Contents containers. The maximum weight of the packaging is 250 lbs, with a maximum payload of 100 lbs, and a maximum gross weight of 350 lbs.

The drum design meets the performance requirements of 49 CFR 178, for an open head drum, but is modified with a bolted-flange closure. The closure does not incorporate a gasket. The drum body is a closed unit consisting of a shell, top deck plate, reinforcing rim (vertical flange) and a liner assembly, with the volume between the liner assembly and drum shell filled with shock-absorbing thermal-insulating materials. The drum shell and liner are fabricated of 18-gage (0.048-inch) Type 304L stainless steel (SS). The drum shell incorporates a "sanitary" style drum bottom, which incorporates a radiused edge which is butt welded to the side wall. The drum bottom includes a rolled "wear ring," 0.060-inch thick by ¾-inch inside diameter (ID), attached by

6a. Date of Issuance: MAR - 1 2008	6b. Expiration Date: October 31, 2012

FOR THE U.S. DEPARTMENT OF ENERGY

7a. Address (*of DOE Issuing Office*)	7b. Signature, Name, and Title (*of DOE Approving Official*)
U.S. Department of Energy Safety Management and Operations, EM-60 1000 Independence Avenue, SW Washington, DC 20585	Dae Y. Chung Headquarters Certifying Official Deputy Assistant Secretary Safety Management and Operations (EM-60)

welds that are external to the drum shell. The drum's top deck plate is fabricated of $^3/_{16}$-inch thick Type 304L SS plate. The top portion of the drum incorporates a $^3/_{16}$-inch thick reinforcing rim (vertical flange) and reinforces the drum head and protects both the closure lid and the bolts during Hypothetical Accident Condition (HAC) events. The rim includes eight (8) 1-inch diameter drain holes that are qualified as package lifting and tie-down points. Drum construction details are shown on drawings R-R2-G-00017 and R-R2-G-00018. As applicable, the drum is designed, analyzed and fabricated in accordance with Section III, Subsection NF of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME BPVC), as listed in Table 9.6 of the SARP.

Four (4) ¾-inch diameter vent holes are drilled at locations around the drum, approximately 90° apart and at each of three elevations, for a total of twelve vent holes along the drum sidewall. Five additional holes, two 1-inch diameter fill holes and three ¾-inch diameter vent holes are located on the drum bottom. All of the holes are covered with appropriately sized Caplug® fusible plastic plugs. During an HAC fire event, the plugs combust or melt, allowing the drum to vent gases generated by intumescing foam insulation. The vent holes ensure that the drum cannot be ruptured by gas pressure.

The drum closure lid is fabricated from ⅛-inch thick Type 304L SS plate. Eight (8) 5/8-inch by 1¼-inch long heavy hex-head bolts with 5/8-inch plain, narrow Type B washers secure the lid to the top deck plate of the drum body. The closure lid incorporates chambers above and below the Lid Plate filled with shock-absorbing thermal-insulating materials. The Lid Top and Lid Bottom chambers are fabricated of 18-gage (0.048-inch) and 14-gage (0.07-inch) Type 304L SS, respectively. The top of the Lid Top is approximately 0.275 inches below the top surface of the drum-head reinforcing rim. The Lid Bottom chamber reinforces the Lid Plate and provides additional thermal protection and shock absorption for the Containment Vessel during HAC events. The Lid Top chamber also reinforces the Lid Plate, adds thermal protection to the contents, and prevents the closure lid from shearing away from the bolts during HAC events.

Four (4) ¼-inch diameter holes through the Lid Plate allow the Lid Top and Lid Bottom volumes to exchange gases and equilibrate pressure. The Lid Top chamber is vented by four (4) ¼-inch diameter holes also covered with Caplug® fusible plastic plugs. The Caplugs® prevent water from entering the lid through the vent holes under Normal Conditions of Transport (NCT). In a HAC fire event, the plugs combust or melt, allowing the lid to vent heated air from the Lid Top and Lid Bottom chambers.

To simplify drum-closure operations, the threaded inserts that receive the drum-closure bolts are welded to the underside of the drum's top deck plate. During installation, the bolts are tightened to a torque value of 45 (±5) ft-lb. The bolt heads are drilled through with a ⅛-inch hole to receive Tamper-Indicating Devices (TIDs). Details are shown on Drawing R-R1-G-00020.

Two layers of insulation material fill the volume between the drum liner and shell. First, two ½-inch thick blankets of Fiberfrax® insulation are wrapped around and attached to the sides and bottom of the liner. The Fiberfrax® is backed on both sides with fiberglass cloth held in place by fiberglass thread stitched longitudinally at 4-inch intervals. The fiberglass cloth gives the Fiberfrax® composite both mechanical strength and wear resistance and helps retard gas flow during the HAC fire event. The remaining volume between the Fiberfrax® and the drum wall is filled with General Plastics FR-3716 polyurethane foam (also known as Last-A-Foam®), poured through fill holes in the drum bottom and foamed in place. The nominal densities of Fiberfrax® and FR-3716 foam are 7-to-10 lb/ft^3 and 16 lb/ft^3, respectively. The thermal-physical properties of Fiberfrax® and FR-3716 are listed in Tables 2.9, 2.10, and 3.8 of the SARP. The combined thickness of the two insulators is approximately 4.95 inches radially (i.e., between the liner and the drum shell) and approximately 4.52 inches axially (i.e., between the liner bottom and drum bottom). Details are shown in Drawings R-R1-G-00020, R-R2-G-00017, and R-R2-G-00019.

The closure lid incorporates two chambers of insulation. The Lid Top chamber contains a 1-inch thick, 14-inch diameter disk of Thermal Ceramics Min-K 2000® insulation. The Lid Bottom chamber contains a rigid disk of Thermal Ceramics TR-19® Block insulation, 4.3-inch thick by 8-inch diameter. When installed, the TR-19® disk compresses two (2) 8-inch diameter by ½-inch thick blankets of Fiberfrax® insulation to a total thickness of ½ inch. The total axial thickness of both the insulators is approximately 5.75 inches. Details are shown in Drawing R-R2-G-00018.

The 9977 is designed with a CV with a nominal ID of six (6) inches (i.e., the 6CV). The 6CV is a stainless steel pressure vessel designed, analyzed and fabricated in accordance with Section III, Subsection NB of the ASME Code, with design conditions of 800 psig at 300°F, as listed in Table 9.5 of the SARP. The 6CV is fabricated from 6-inch, Schedule 40, seamless, Type 304L SS pipe (0.280-inch nominal wall). A standard Schedule 40 Type 304L SS pipe cap (also 0.280-inch nominal wall) is welded to the pipe segment to form a blind end. A stayed head is machined from a 7½-inch diameter by 2¼-inch long Type 304L SS bar and is welded to the open end of the pipe segment, completing the vessel body weldment. The head is machined to include 6½-12UNS-2B internal threads and an internal cone-seal surface with a 32-micro-inch finish. Both vessel body joints are Category B, full-penetration, complete-fusion, circumferential welds. A support skirt to stand the 6CV vertically is formed from a short segment of 5-inch, Schedule 40 Type 304L SS pipe welded to the convex side of the cap. Two rectangular notches milled into the bottom edge of the skirt (180° apart) can engage a rectangular key to prevent vessel rotation during removal and installation of the closure assembly.

The 6CV Closure Assembly consists of a Type 304L SS Cone-Seal Plug shaped in part like a truncated cone and a threaded Cone-Seal Nut made from Nitronic 60 SS. The two Closure Assembly components rotate freely relative to one another and are coupled by a snap-ring that also ensures unseating of the closure seal during disassembly. As the Cone-Seal Nut is threaded into the stayed head of the vessel, the Cone-Seal Plug is thrust axially against the corresponding cone-seal surface of the vessel. Both internal and external sealing surfaces are machined to the same angles, surface finishes, and with matching diameters so that they mate with radial clearance of 0.0007 inches. To minimize the potential for thread galling, the Cone-Seal Nut and the Containment Vessel body are made from dissimilar materials. Two O-ring grooves (outer and inner) are machined in the face of the external Cone-Seal Plug. Viton® GLT/GLT-S O-rings fit into these grooves to complete the leaktight closure assembly.

For operator safety, a 0.094-inch diameter vent hole is located in the stayed head between the threads and the internal sealing surface. The vent hole is clocked 90° from the notches in the vessel support skirt. Unscrewing the Cone-Seal Nut a few turns will unseat the Cone-Seal Plug from the internal cone-seal surface and route any pressurized gases from the CV through the vent hole.

A leak-test port is incorporated into the Cone-Seal Plug and connected by a drilled radial passage to the annular volume between the two O-ring grooves in the Cone-Seal Plug. The leak-test port provides a means of verifying proper assembly of the vessel closure and is itself closed by the Leak-Test Port Plug. The vessel containment boundary is formed by the vessel body weldment, the Cone-Seal Plug, the Leak Test Port Plug, and the Outer O-ring.

The internal volume of a closed 6CV is approximately 608 cubic inches. The nominal assembly weight is 52.3 lb, and the nominal overall length is 24.03 inches. The usable cavity of the 6CV is

The internal volume of a closed 6CV is approximately 608 cubic inches. The nominal assembly weight is 52.3 lb, and the nominal overall length is 24.03 inches. The usable cavity of the 6CV is a minimum of 20.25 inches deep with a minimum diameter of 5.95 inches. Details are shown in Drawing R-R2-G-00042.

The Top and Bottom LDFs are made from 6061-T6 aluminum round bar and fit within the Drum Liner cavity, above and below the 6CV. The LDFs center the 6CV in the liner, stiffen the package in the radial direction, and distribute loads away from the 6CV. The 6CV fits directly into the LDFs. Details are shown in Drawing R-R4-G-00032.

Figure 1 is a Three-Dimensional (3D) Cut Away Illustration of the 9977.

The 9977 is evaluated for shipment of radioactive contents containing Assemblies of Radioisotope Thermoelectric Generators (RTGs), and/or Food-Pack cans, Content C1. Two different sizes of RTGs (the MC2730 and MC3500) can be shipped within a single 9977 configuration. The RTGs are placed within vibration-limiting and thermal-conducting assemblies. One RTG Assembly holds a maximum of four (4) RTGs. Either or both sizes of RTGs may be shipped in the same assembly. The RTG assembly configuration positioned in the 6CV is shown in Figure 2.

The term "food-pack" can includes metal cans with crimped-seal closures, "slip-lid" closures, or site-specific "convenience containers." Crimp-sealed food-pack cans are typically fabricated in accordance with Federal Specification PPP-C-96E or equivalent, and meet the size specification as defined by the Can Manufacturers Institute — Voluntary Can Standards. Convenience containers are typically application-specific designs that incorporate screw thread, crimp-sealed, or welded closures. These three types of cans are made typically from tin-plated mild steel or stainless steel.

Actinide oxides and other materials may be placed inside food-pack cans prior to placing items in the packaging. An elastomeric gasket material or polyvinyl chloride tape may be applied to the edge of the can lid. The seal material may limit the spread of contamination, but is not credited for any measure of containment within the package.

The can containing the radioactive material is typically placed inside low-density polyethylene or nylon bagging for contamination control. Multiple bags may be present, up to the mass limit for plastics. The bagged inner can is typically then nested within one or more outer cans. The nested assemblies are then placed within the 6CV.

Nesting of food-pack cans is not required (i.e., a single food-pack can is allowed). Food-pack cans may be arranged for handling convenience and contamination control into single, double, or triple-stacked configurations, provided the general requirements listed in Section 1.2.2 of the SARP are satisfied and the food-pack can requirement in Section 1.2.2.2.1 of the SARP is fulfilled.

The 9977 is also evaluated for shipment of radioactive contents from the Addendum [See 5(e)(2)]. Content Envelopes AC.1 through AC.5 include the following: Neptunium metal; either as the "Neptunium Sphere" or as metal pieces; the BeRP Ball; as a ^{239}Pu metal sphere in an aluminum heat-sink holder; plutonium and uranium metals; plutonium and uranium metals with a higher ^{240}Pu limit but with reduced total mass limit; and Highly Enriched Uranium (HEU) metal.

contamination of the package by providing a level of confinement for the radioactive material contents and to provide protection of the content being shipped. These content containers are also referred to as product containers. Descriptions, illustrations, and the packaging limitation for these configurations are provided in the Addendum [See 5.e(2)] Sections 1.2.2.1.1, 1.2.2.1.2, and 1.2.2.1.3.

The 9977 is also evaluated for shipment of radioactive contents in a specialized Engineered Container configuration, the Isentropic Compression Experiment (ICE) test apparatus, which consists of a stainless steel assembly containing approximately 8 gm of ^{239}Pu or its dose equivalent, within the mass limits of the ICE Radioactive Contents [Table 1 in Reference 5.(e)(3)]. The ICE apparatus contains no plastics other than Viton® O-rings. The apparatus weighs less than 30 lb. The packing system, designed to protect the ICE apparatus from normal transport vibrations, consists of two (2) sets of Spring Mounts (6061-T6 aluminum), springs (ASTM A 288 QQW-470 steel music wire), and 2¼-inch square by 3½ inch long Foam Bumper Blocks (General Plastics Last-A-Foam®, TF-5070-10). The ICE assembly configuration positioned in the 6CV is shown in Figure 3.

Neither 9977 materials nor component geometry provide significant radiation shielding. Dose-rate attenuation is provided primarily by the distance between the source and points external to the package.

The 9977 design does not incorporate materials specifically for the purpose of poisoning or moderating neutron radiation. Subcriticality is ensured by limiting the package fissile material mass.

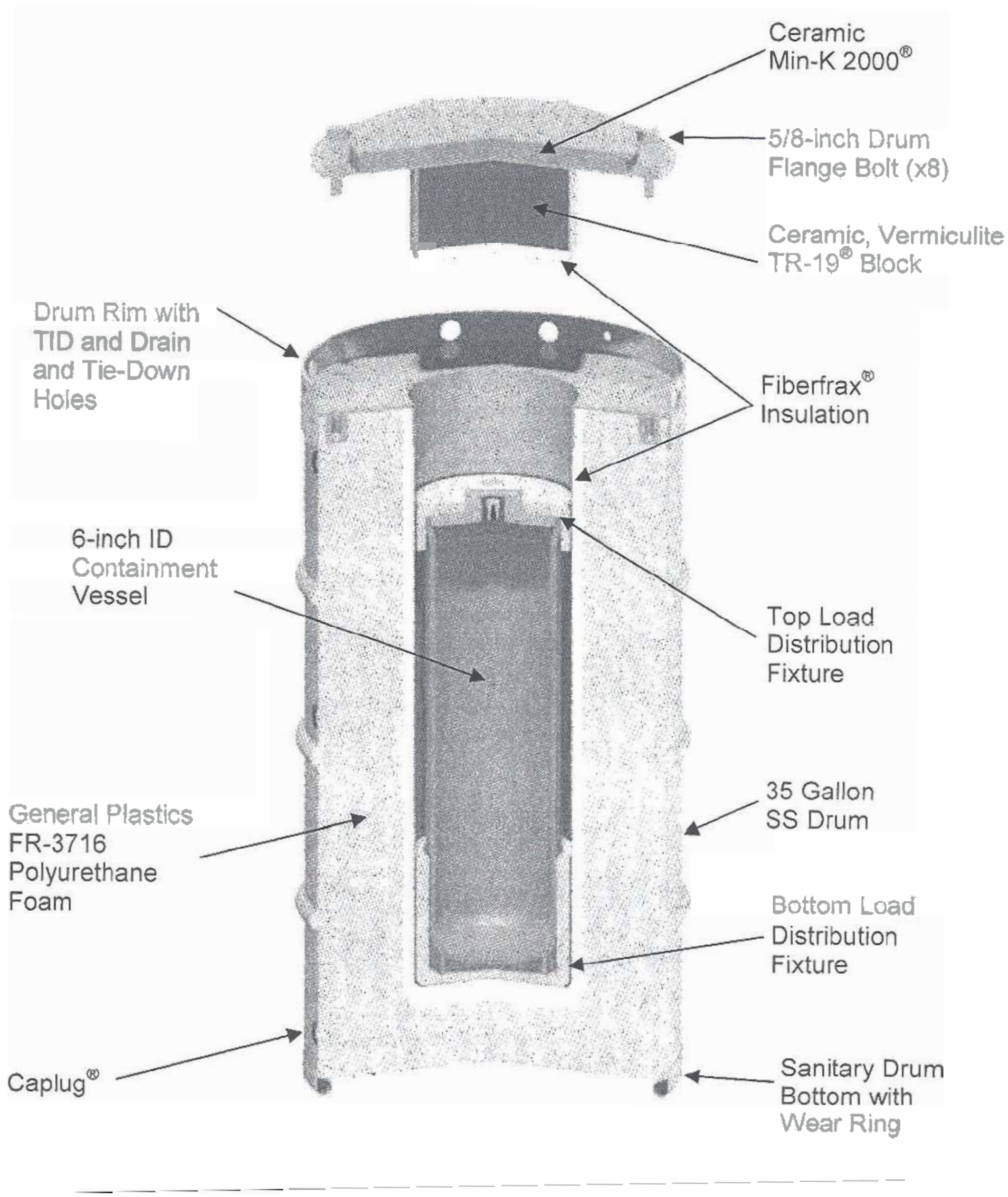

Figure 1: Three-Dimensional Cut Away Illustration of the 9977

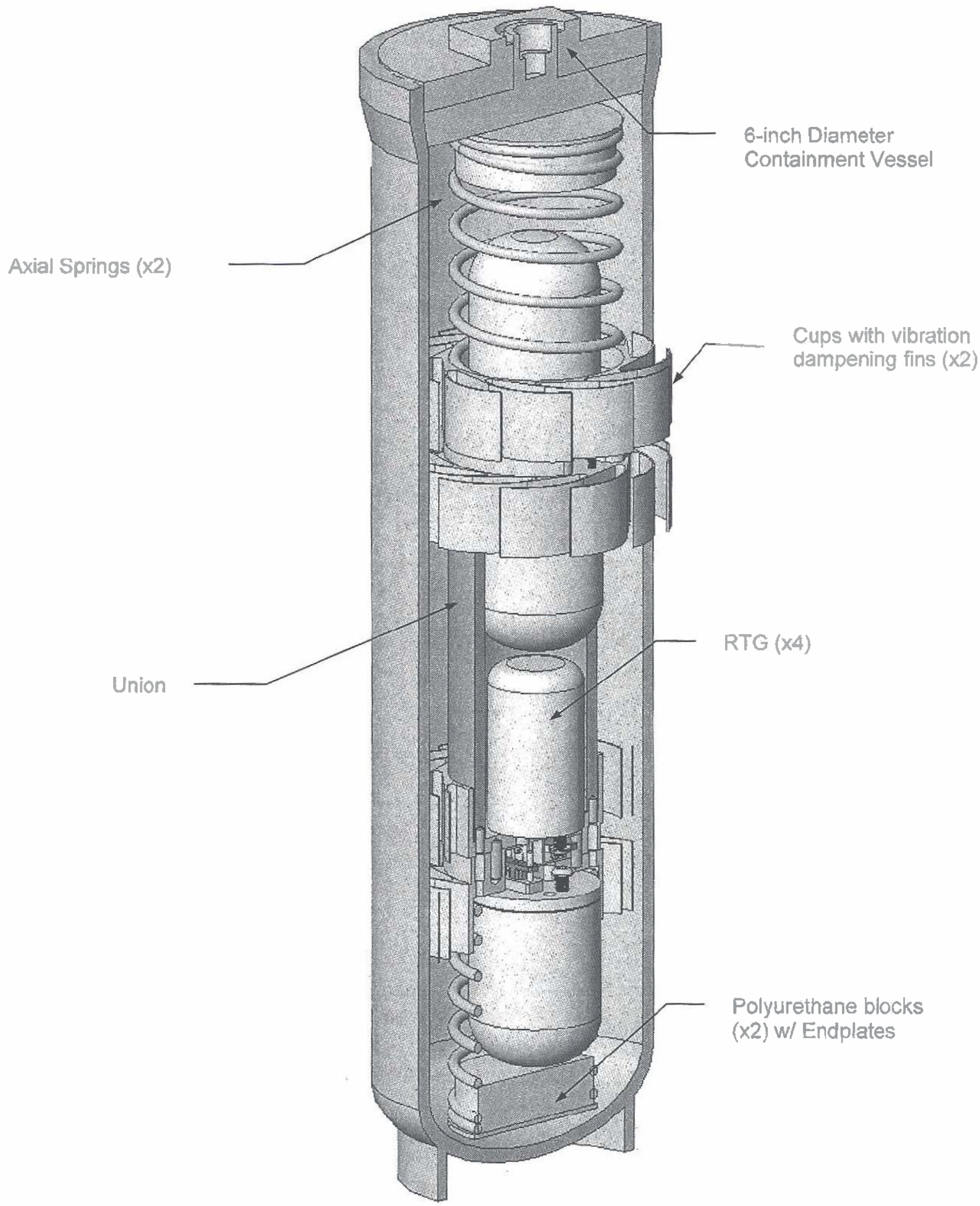

Figure 2: 6CV w/Radioisotope Thermoelectric Generator (RTG) Assembly

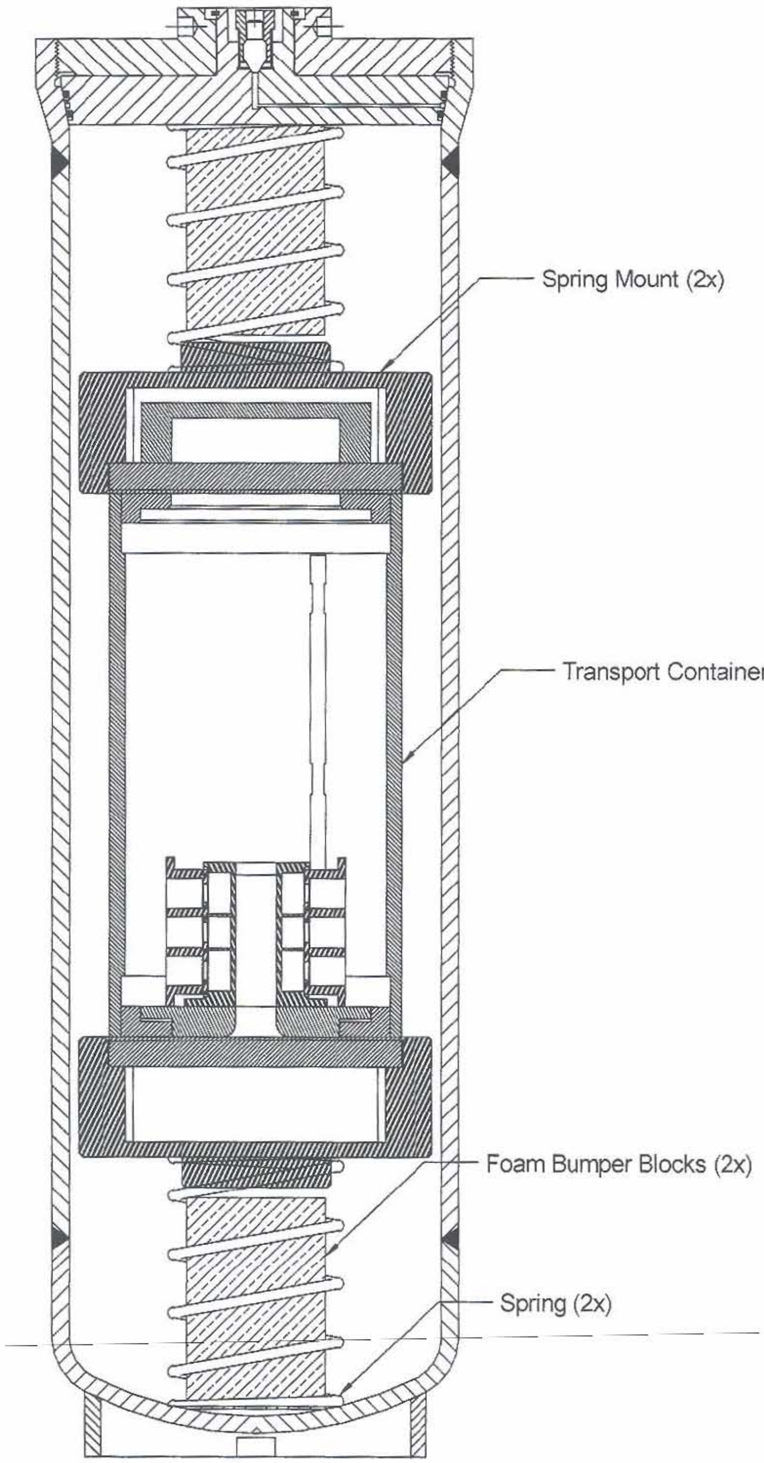

Figure 3: 6CV w/ICE Apparatus Transport Container Assembly

(3) Drawings:

The packaging design is defined by the following Savannah River Site drawings:

R-R1-G-00020, Revision 2; 9977-Assembly with 6-inch Diameter Containment Vessel (U)

R-R2-G-00017, Revision 1; 9977-Drum and Liner Subassembly (U)

R-R2-G-00018, Revision 2; 9977- Drum Lid Subassembly (U)

R-R2-G-00019, Revision 1; 9977-Insulating Blanket Subassembly (U)

R-R2-G-00042, Revision 2; 9977-Six Inch Diameter Containment Vessel Subassembly (U)

R-R4-G-00032, Revision 1; 9977-Load Distribution Fixtures Details (U)

R-R4-G-00053, Revision 1; 9977-Sleeve and Plug Details (U)

Drawings for the ICE Container Assembly:

R83700, LANL Transport Container Assembly

1001-0269-0000, Platform, Pu Anode, Inner

1103-0355-0000, Panel, ICE, Floor

1103-0388-0000, Panel, 17mm Spacer, ICE

1103-0389-0000, Plug, Panel, 17mm Spacer

1350-2333-0000, Fitting, 1/8 to 1/8, Custom

1350-2357-0000, 90° Adaptor Fitting

1350-2495-0000, Probe Nut

1350-2496-0000, Mount, Probe Body, 3-Point

R83710, Transport Container Handle

R83711, Transport Container Anode Mount

R83712, Transport Cannister Body

R83722, Transport Container Strain Relief

2-045, Viton O-Ring

502-440-716-AAA2, Socket Head Cap Screw, alloy steel

502-1420-1-AAA2, Socket Head Cap Screw, alloy steel

(b) Contents

(1) Type and Form of Radioactive Material:

Package contents identified as Content Envelope C.1 and ICE are defined in Table 1 and packaging contents identified as Content Envelopes AC.1 through AC.5 are defined in Table 3. The contents are in solid form as metal pieces or oxides. Contents in liquid form are not permitted.

(2) Maximum Quantity of Radioactive Material per Package:

(a) Envelope C.1, Heat Sources and ICE. The total content mass listed in Table 1 excludes material containers and packing materials (i.e., RTG containers, springs, cups and union).

Contents containers and content-specific configuration requirements are listed in Sections 1.2.2.1 and 1.2.2.2 of the SARP [See 5.(e)(1)].

Compatibility of the packaging materials of construction, packing materials, and the contents is discussed in Section 2.2.2 of the SARP [See 5.(e)(1)]. There are no material incompatibilities in the package. Since the 6CV is leaktight, it may become pressurized by heating of gases contained at the time of closure and pressurized further by gases generated from radioactive decay of the contents. The contents do not generate fission gases. The Maximum Normal Operating Pressure (MNOP) for the 6CV is 41.2 psig.

Except as stated in Table 1, small concentrations (<1000 ppm each) of other actinides, fission products, decay products, and neutron activation products are permitted. Assessment of these impurities may be based on process knowledge.

Except as stated in Table 1, inorganic material impurity quantities of less than 100 ppm each are permitted as long as the total mass is less than 0.1 weight percent of the total content mass. Assessment of these impurities may be based on process knowledge.

Content Envelope C.1 and ICE requirements are summarized in Table 2 by content envelope and container configuration.

Table 1- Contents

	Material [a, b]	C.1 Heat Sources weight%	C.1 Heat Sources grams	ICE Weight%	ICE grams[e]
Radioisotope	^{238}Pu	100	100	0.04	0.03
	^{239}Pu [c]	40	40	100	8
	^{240}Pu [d]	13	13	6	2.2
	^{241}Pu [c]	1	1	0.2	0.005
	^{242}Pu	1.5	1.5	0.06	8[f]
	^{241}Am			g	0.14
	^{232}U [c]	1.4×10^{-4}			
	^{233}U [c]	0.2			
	^{234}U	40			
	^{235}U [c]	40			
	^{236}U	16			
	^{238}U	40			
Impurities (grams)	Ca	15			
	Fe	5			
	Cr	2			
Total Mass (kg)	Radioactive Materials	0.1	100		8
	Impurities	0.02	20		
	All Contents	0.1	100		8

Notes

- a All contents shall be dry.
- b Pu/U content bulk density shall be no greater than 19.84 g/cc and no less than 2.0 g/cc.
- c Nucliae classified as "fissile" per DOE Good Practices Guide, Criticality Safety Good Practices Program, Guiae For DOE Nonreactor Nuclear Facilities, DOE G 421.1-1, 3.79 Fissile Nuclide, 8-25-99.
- d ^{240}Pu shall be greater than ^{241}Pu.
- e Mass limit based on 8-gram ^{239}Pu dose equivalence
- f The 239Pu dose equivalent mass is 125 grams, the content Total Mass limit takes precedence.
- g ^{241}Am exists at the 9977 SARP Rev.2 impurity limit of 100 ppm.

Table 2- Summary of Requirements by Content and Configuration

Content Envelope	Container Configuration		
	Food-Pack Can	**SNL RTGs**	**ICE Assembly**
C.1	maximum 100 g plastic (low-density polyethylene, nylon, and/or polyvinyl chloride tape)	manufactured per drawings listed packing configuration control maximum 100 grams polyurethane	
ICE			maximum 8 g radioactive materials maximum 100 g plastic manufactured per drawings listed
All	19 watts maximum radioactive decay heat rate less than 1000 ppm other radionuclides (unless otherwise stated in Table 1.2) less than 100 ppm other inorganic impurities with total mass less than 0.1 weight percent (unless otherwise stated in Table 1.2) 100 lb maximum content weight (radioactive contents, convenience cans, contamination control devices, packing materials, spacers, etc.)		

(b) Envelope AC.1, Neptunium Metal. Section 1.2.2.2.1 of the Addendum [See 5.e(2)] provides figures and drawing numbers of Neptunium Metal Spheres and Storage Containers.

The two possible neptunium content configurations are shown in Figure A.1.2. of the Addendum [See 5.e(2)]. One configuration for this content envelope is the Neptunium Sphere which is a solid sphere of neptunium metal with cladding and shielding around the sphere, aluminum foil as dunnage, and a Vollrath convenience can. Additionally, this content may incorporate a configuration within the convenience can where an aluminum Storage Container is placed around the neptunium sphere assembly. The masses of the tungsten shielding shell and the two nickel cladding shells are added to the mass of neptunium for a total assembly mass of 8026.9 grams.

The mass of the aluminum Storage Container is estimated at 3100 grams. Assuming that the density of crushed aluminum foil is about ½ that of a cast billet, the mass of aluminum foil inside the Vollrath can is estimated to be 790 grams. Additional aluminum foil will serve as dunnage outside the Vollrath can, but its mass depends on the size of the empty dunnage can. Assuming the shipper selects a standard 404 x 700 food-pack can (4.25" diameter by 7" tall); the estimated mass of additional aluminum foil needed to fill the axial space above and/or below is 540 grams. The estimated maximum mass of aluminum, including fixture and foil, is 4430 grams. The mass of the alternative packaging configuration (aluminum foil dunnage only without the handling convenience fixture) will be less.

The Vollrath 88020 can serves as a handling convenience. The stainless steel can will be sealed by a wrapping of tape where the lid rests on the can body. The loaded Vollrath Can will be placed into the 6CV in the Sleeve and Plug configuration. The remaining space above the Vollrath can may be packed with an empty food pack can and/or aluminum foil as final dunnage.

Neptunium metal pieces to a maximum mass of 188 grams may be shipped under this content envelope. These pieces must be packaged in Food-Pack Cans or Engineered Containers.

(c) Envelope AC.2, BeRP Ball. Section 1.2.2.2.2 of the Addendum [See 5.e(2)] provides figures and drawing numbers of Plutonium Ball and heat-sink fixture drawing.

The BeRP Ball is a Beryllium Reflected Plutonium Ball that contains 4484 grams of alpha-phase plutonium. Radioactive decay heat from the plutonium sphere is 10.656 watts which is much less than the package limit of 19 watts. Added to the mass of plutonium is the mass of the stainless steel shell for a total assembly mass of 4.5 kg. Table 4 presents configuration requirements for the Plutonium Ball content.

The mass of the aluminum heat-sink fixture is estimated conservatively at 3100 grams. Conservatively assuming that the density of crushed aluminum foil is about half that of a cast billet, the mass of aluminum foil inside the Vollrath can is estimated to be 790 grams. Additional aluminum foil will serve as dunnage outside the Vollrath can, but its mass depends on the size of the empty dunnage can. Assuming the shipper selects a standard 404 x 700 food-pack can (4.25" diameter by 7" tall) as dunnage, the estimated mass of additional aluminum foil needed to fill the axial space above and/or below the food-pack can is 540 grams. The estimated maximum mass of aluminum, including fixture and foil, is 4500 grams.

The Vollrath 88020 is a slip lid convenience can. The stainless steel can will be sealed by a wrapping of tape where the lid rests on the can body. The loaded Vollrath can will be placed into the 6CV, followed by one empty and perforated food-pack or empty and unsealed slip-lid can to serve as dunnage. The space between the Vollrath can and the dunnage can and between the dunnage can and the top of the vessel will be packed with aluminum foil as final dunnage.

(d) Envelopes AC.3 and AC.4, Pu/U Metals. Section 1.2.2.2.3 of the Addendum [See 5.e(2)] provides figures and more details for these content envelopes.

Content Envelopes AC.3 and AC.4 must be loaded into the containment vessel with the incorporation of an aluminum Sleeve and Plug. The (one-piece) aluminum Sleeve and Plug component reduces the volume of the containment vessel in order to meet the Single Package Flooded condition requirement for sub-criticality found in 10 CFR 71.55, General Requirements for Fissile Material Packages. For array analyses, the aluminum Sleeve and Plug also provides spacing in order to meet the requirement for sub-criticality. The aluminum Sleeve and Plug also provides spacing in order to meet the requirement NCT Dose limit requirements.

These contents are packaged in 3013 containers, food-pack cans, or engineered containers and the product container is loaded into the containment vessel after the Sleeve and Plug has been installed. The general requirements for all packages as documented in Addendum Section 1.2.2 apply to these contents.

For Content Envelope AC.3, if the radionuclide content mass is equal to or greater than 3 kg per innermost material container, the following restrictions apply:

- The sum of the radial wall thicknesses of all nested cans shall not exceed 0.26 inch.
- The sum of the thicknesses of the tops and bottoms of all nested cans shall not exceed 1.77 inches.

- The innermost material container shall be at least 4 inches in diameter and at least 4 inches long (i.e., minimum can size 400 x 400).

For Content Envelope AC.4 material with a mass less than or equal to 450 grams, the requirement to use of the aluminum Sleeve and Plug does not apply. Contents meeting these conditions and packaged in 3013 containers, food-pack cans, or an engineered container are permitted to be loaded into the containment vessel with no additional packaging requirements. Aluminum foil may be placed around the product container as dunnage to restrict movement within the containment vessel.

(e) Envelope AC.5, U Metal. Section 1.2.2.2.4 of the Addendum [See 5.e(2)] provides figures and more details for this content envelopes.

Content Envelope AC.5 maximizes the Highly Enriched uranium metal, alloyed with up to 10% molybdenum, which may be shipped in the 9977. This content must be packaged in a 3013 container, a food-pack can, or an engineered container. The convenience container must be placed within a (one-piece) aluminum Sleeve and Plug component followed by an empty, perforated food-pack can, followed by aluminum foil dunnage. Aluminum foil may be placed around the product container as dunnage to restrict movement within the containment vessel. Requirements applicable to all packages as documented in Addendum [See 5.5(2)] Section 1.2.2 apply to this content envelope.

The Content Envelope AC.5 separate mass limit is dependent upon its percent enrichment. Contents with less than 95% ^{235}U have a mass limit of 18 kg. Content with enrichment greater than 95% (to a maximum of 100 %) ^{235}U have a mass limit of 16 kg. For Content Envelope AC.5, if the radionuclide content mass is equal to or greater than 3 kg per innermost material container, the following restrictions apply:

- The sum of the radial wall thicknesses of all nested cans shall not exceed 0.26 inch.

  The sum of the thicknesses of the tops and bottoms of all nested cans shall not exceed 1.77 inches.

- The innermost material container shall be at least 4 inches in diameter and at lease 4 inches long (i.e. minimum can size 400 x 400).

Table 3 - Content Envelopes

	Material [a,b]	AC.1 Neptunium Metal	AC.2 BeRP Ball Metal	AC.3 [c] Pu/U Metal	AC.4 [c] Pu/U Metal	AC.5 [c] U Metal
Radioisotope (Weight Percent of Radioactive Material Mass)	^{238}Pu	1.6×10^{-3}	0.02	2	2	
	^{239}Pu [d]	3.2×10^{-2}	93.74	100	100	
	^{240}Pu [e]	2.3×10^{-3}	5.94	25	50	
	^{241}Pu [d]	6.2×10^{-5}	0.272	15	15	
	^{242}Pu	3.2×10^{-4}	0.028	5	5	
	$^{241}Am + ^{241}Pu$	7.2×10^{-4}	0.272	15	15	
	^{243}Am	0.18				
	^{237}Np	98.8 [f]				
	^{232}U [d]			1×10^{-7}	1×10^{-7}	1×10^{-7}
	^{233}U [d]	3.5×10^{-3}		0.5	0.5	0.5
	^{234}U	5.7×10^{-4}		100	100	100
	^{235}U [d]	2.8×10^{-2}		100	100	100/95 [g]
	^{236}U	1.6×10^{-4}		40	40	40
	^{238}U	3.1×10^{-3}		100	100	100
Impurities [h] (%)	Al, B, F, Li, Mg, Na					
	Be					
	Mo					10
	C					
Total Mass (kilograms)	Radioactive Materials	0.188/6.07 [i]	4.48	4.4	0.45/2 [j]	16/18 [g]
	Impurities		0.0215	3.08 [k]		
	All Contents	0.188/6.07 [i]	4.5	4.4	0.45/2 [j]	16/18 [g]

a. All contents shall be dry.
b. Pu/U content bulk density shall be no greater than 19.84 g/cc and no less than 2.0 g/cc.
c. Contents shall be stabilized in accordance with DOE-STD-3013, Section 6.1.1.
d. Nuclide classified as "fissile" per DOE Good Practices Guide, Criticality Safety Good Practices Program, Guide For DOE Nonreactor Nuclear Facilities, DOE G 421.1-1, 3.79 Fissile Nuclide, 8-25-99
e. ^{240}Pu shall be greater than ^{241}Pu
f. 100-year accumulation of daughter products incorporated into thermal and nuclear safety evaluations.
g. The content mass limit is based on the percentage of ^{235}U. 16 kg of Content with up to 100 wt% ^{235}U are allowed. 18 kg of Content with up to 95 wt% ^{235}U are allowed.
h. Less than 0.005 grams of (α, n) impurities {aluminum, beryllium, boron, fluorine, lithium, magnesium, and sodium} are permitted.
i. The mass limit is based on the content configuration. 6.07 kg is allowed as the Np Sphere configuration. 188 grams is allowed if the content consists of pieces.
j. The mass limit is based on the content packing configuration. 2 kg of Content in the Sleeve and Plug configuration is allowed. 450 grams of Content placed directly into the 6CV is allowed.
k. The impurity limit is based on the DOE-STD-3013 requirement that plutonium plus uranium mass shall not be less than 30 weight percent of the total content mass

Table 4 - Summary of Packaging Configuration Requirements

Content Envelope	Configuration	
	Food-Pack Cans or Engineered Containers	**3013**
AC.1 Neptunium Metal Sphere Or Pieces	• aluminum Sleeve and Plug required • maximum content 188 grams if pieces • maximum 100 grams plastic • maximum 2000 grams stainless steel cans (Vollrath) • maximum 4500 grams aluminum (heat-sink fixture and/or foil)	NA
AC.2 BeRP Ball	• maximum 100 grams plastic • maximum 2000 grams stainless steel cans (Vollrath) • maximum 4500 grams aluminum (heat-sink fixture and/or foil)	NA
AC.3 Pu Metal	• aluminum Sleeve and Plug required • maximum 100 grams plastic • if ≥ 3kg per food-pack can * sum of can walls < 0.26 inches * sum of can tops & bottoms < 1.77 inches * 400 x 400 can or bigger	• aluminum Sleeve and Plug required • if ≥ 3kg per inner/material can * sum of can walls < 0.26 inches * sum of can tops & bottoms < 1.77 inches * 400 x 400 can or bigger
AC.4 Pu Metal	• aluminum Sleeve and Plug required (unless total radioactive contents mass is less than 450 grams) • maximum 100 grams plastic	• aluminum Sleeve and Plug required (unless total radioactive contents mass is less than 450 grams)
AC.5 U Metal	• aluminum Sleeve and Plug required • maximum 100 grams plastic • if ≥ 3kg per food-pack can * sum of can walls < 0.26 inches * sum of can tops & bottoms < 1.77 inches * 400 x 400 can or bigger	• aluminum Sleeve and Plug required • if ≥ 3kg per inner/material can * sum of can walls < 0.26 inches * sum of can tops & bottoms < 1.77 inches * 400 x 400 can or bigger
All	• 19 watts maximum radioactive decay heat rate • less than 1000 ppm other radionuclides (unless otherwise stated) • less than 100 ppm other inorganic impurities with total mass less than 0.1 weight percent (unless otherwise stated) • 100 lb maximum content weight (radioactive contents, product cans, Sleeve and Plug, etc.)	

Note: Can wall thickness limits are driven by criticality concerns and do not apply to the Neptunium Metal Sphere or Parts

(c) Criticality Safety Index

The Criticality Safety Index CSI for package with Content Envelope C.1 or ICE is zero. (CSI=0) The Criticality Safety Index CSI for the package with Content Envelope AC.1 through AC.5 is 1.0 (CSI=1.0)

(d) Conditions:

(1) The maximum allowable radioactive decay heat rate is 19 watts

(2) The maximum weight of the payload (everything that goes into the 6CV, including radioactive contents, convenience cans, contamination control devices, packing materials, spacers, etc.) is not to exceed 100 lb.

(3) The Model 9977 Package must be shipped in a closed conveyance.

(4) Transport of fissile material by air is not authorized.

(5) In addition to the requirements of Subparts G and H of 10 CFR Part 71, and except as specified in section 5(d) of this certificate, each package must be fabricated, acceptance tested, operated, and maintained in accordance with the Operating Procedures requirements of Chapter 7, Acceptance Tests and Maintenance Program requirements of Chapter 8, and packaging-specific Quality Assurance requirements of Chapter 9 of the SARP [See 5.(e)(1)] as supplemented by the Addendum [See 5.(e)(2)] and the Application [See 5.(e)(3)].

(e) References

(1) *Safety Analysis Report for Packaging, Model 9977 B(M)F-96*, S-SARP-00001, Revision 2, August 2007

(2) *Safety Analysis Report for Packaging, Model 9977 Addendum 2, Justification for Metal Contents,* S-SARA-G-00005, Revision 1, December 16, 2008.

(3) *Application for Contents Amendment for Shipping Isentropic Compression Experiment (ICE) Apparatus in 9977 Packaging*, National Nuclear Security Agency Memorandum from Paul T. Mann, Facility Operations Division, NA-172.1, to James M. Shuler, Office of Packaging and Transportation Safety, EM-63, Revision 2, February 20, 2009.